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## 0.0. TECHNICAL REPORT SUMMARY

The object of this project is extend our earlier findings based on simple stimulus materials to the mastery of information from complex and meaningful stimulus materials. One major question is how do individuals represent (or encode) the information in meaningful input. A related question is how can we, as experimenters, best represent such information. For practical reasons we need a way to describe the knowledge contained in input if we are to assess just what and how much an individual has gained from a learning experience. For theoretical reasons we need a model of how the individual represents this knowledge in order to ask questions about how his particular representation interacts with the format of the instructional material.

During the past six months we have devoted much effort towards developing an integrated framework within which to organize our own work and that from other laboratories. The framework tries to conceptualize what the individual brings with him to the learning experience--his prior knowledge and beliefs, how they are organized, his expectations and his goals--and what the instructional materials communicate to the learner--starting with the purely sensory aspects, the patterns, and the information being represented. Somehow the eventual result of a learning experience must be a product of centrally-guided processes--prior information and expectations and hypotheses--and peripherally-guided processes--unexpected sensory patterns and new information that they convey.

In January the new Prime computer system arrived. We began, this summer, to overhaul the entire software system that accompanies our PDP-15. And

we have started the complex process of devising a software system that will enable us to integrate the Prime system into our current automated laboratory.

Empirical research, of course, continued along the lines discussed in previous reports. Much of the work has been devoted to the question of how codes and higher order units operate. Some of these questions have been attacked in terms of the word superiority effect. Reicher and Hawkins confirmed previous findings that the effect can be accounted for, in part, by the pronounceability of a letter string. But, and this is their added contribution, they further demonstrated that when pronounceability is controlled or removed from the picture, there still is a word superiority effect. This means that other sorts of coding principles beyond simple pronounceability contribute to the effect.

Janet Polf, with her doctoral dissertation, is looking at another aspect of the word superiority effect. She demonstrated, firstly, that the effect cannot be explained in terms of spending more time processing words and letters in the letter condition. Her data suggest that the phenomenon may involve two stages. In the first stage, the subject processes the sensory input to the point of activating or retrieving a higher order code or unit corresponding (in this case) to a word. The second stage requires the subject to "unpack" this word chunk in order to retrieve a component letter. Hopefully such a finding may give us a clue to how higher order units in general carry component information.

Polf, who is doing her dissertation under Hyman's direction, is studying a phenomenon first discovered by Reicher and applying a technique

developed by Wickelgren and his students. This technique, based on the speed-accuracy trade-off paradigm, has been applied by two of Wickelgren's students to problems in semantic memory. Dosher is completing her Master's Thesis by applying the speed-accuracy paradigm towards the problem of how sentences are represented in memory. And Corbett, also for a Master's Thesis, is applying the paradigm towards the study of various models of how classifications are learned within a semantic field.

Hyman and his colleagues completed a series of experiments using the impression formation paradigm. They concluded that new information can be encoded in generic or specific manner. When the information is consistent with what the subject already knows about a topic, the new input is encoded in such a way as to strengthen existing beliefs rather than to add to or change them. When the new input is not necessarily consistent with what is known, only those specific aspects of the new information are encoded that can be fit into the existing picture. In the former case, not very much is remembered about the input. In the latter case, the input is remembered in rather specific and nongeneric terms.

Hyman has also returned to the paradigm in which a data base is "loaded" into a subject's long term memory. In the earlier work, the data base consisted of a set of nominal propositions about a number of hypothetical individuals. In the current work, the subject learns about the same individuals both nominal propositions (ones that classify and assign properties) and relative propositions (ones that directly specify relationships between individuals). He also learns parts of the information about an object at different times. Hyman then studies the extent to which subjects can

selectively retrieve specified information depending upon how the initial information was learned, its form, and the task context.

Wickelgren continues to turn out a number of theoretical studies both in the area of classical memory and in the area of semantic memory. Reicher has begun some studies to study sophisticated encoding--comparing experts with novices in various fields of information acquisition and usage. Schaeffer will end his participation in this project this summer. He now has his own grant and will devote his research efforts to it.

## 1.0. INTRODUCTION

### 1.1. Objectives.

Our plan is to see how we can apply the findings and procedures from our previous project on "Coding Systems in Perception and Cognition" to meaningful stimuli such as instructional materials. Our previous work investigated the codes and operations that individuals employ in processing information. The information being processed, however, came from variations in relatively small and meaningless sets of auditory and stimulus materials. Will the same models and processes apply when individuals have to cope with information that is more complex, semantically meaningful, and approximates textual and instructional materials in format?

The term "coding systems" indicates that we focus upon the representational aspect of information processing. What are the different codes and ways that individuals represent or encode the given information? Are some ways better than others? Do different representational systems vary in effectiveness depending upon the form of the input material and the task?

"Coding systems" have become important in cognitive psychology for a

number of reasons. In the present context they are important because it is the stimulus-as-encoded that the learner reacts to and retains in memory. Unless an instructor can be sure that the student encodes the materials in a way that is isomorphic to what the course is trying to impart, he will fail in his mission.

"Comprehension" is a slippery term. For one thing it is ambiguous in at least two ways. It can refer both to the act of trying to make sense of information or to the result of such an act. In addition, it refers to a subjective state or feeling and also to an objective assessment of how well an individual has mastered a cognitive task. In the long run we are interested in all of these meanings. But for the short run our focus is upon how effectively an individual can use the information he has recently acquired.

1.2. The General Research Plan

We wanted to see to what extent we could use the experimental designs and paradigms from our preceding work on coding systems. In the best of worlds, we simply would have been able to use the same paradigms with only minor changes needed to accomodate the more complex sorts of stimulus materials and the longer time periods needed for such materials. To some extent, such an "extrapolation" of the earlier work has been carried out, especially in the work of Wickelgren, Schaeffer, Keele, and Reicher for this project.

But such simple extrapolation can carry us only so far. We still have to grapple with how to represent the meaningful material--what sorts of units do we employ, etc. And the new materials raise new questions, both methodological and theoretical, that have no counterparts in the

earlier work. Consequently, a large share of our effort, especially the work of Hyman and his co-workers, has been and will be devoted to the development and testing of novel paradigms.

We expected to devote the first year of this project to a sort of "tooling up" period. During this period we would devise and try-out various new paradigms. Hopefully some of them would show promise for further payoffs. This, in effect, is what Hyman and his colleagues did. Two of the paradigms showed some promise, but--at the same time--they also presented us with many technical problems to overcome. Many of these problems result from the sheer complexity of dealing with meaningful stimulus materials. Even very elementary semantic material has orders of complexity many times higher than what we face with our typical laboratory stimuli.

We expected to devote the second year of the project to perfecting the most promising paradigms. This, too, has in essence been done. Finally, we hoped that the third year would be devoted to fully exploiting the best paradigms and to generating empirical findings.

Hopefully, now that the first two years are over, the rest of the plan will be fulfilled.

Realistically, the completed project should result in the usual product of completed research studies. But, more important, we hope it will generate some new paradigms that can be employed in the future to gain useful information about the instructional process.

1.3. <u>Some further goals.</u>

We have also devoted much time during the second year, and will continue this effort during the third year, to devising a framework within

which to integrate the various projects in semantic memory both within our own laboratory and within other laboratories. Our main vehicle for this purpose has been a continuing seminar organized around the research goals of the current project. We have been fortunate to have participants such as Nancy Frost, Princeton University: Baruch Fischoff, from Israel and now at Oregon Research Institute; and Mickey Rothbart, a Social Psychologist interested in cognitive problems. In the future Art Farley, who did his dissertation under Newell and Simon at Carnegie-Mellon will also join us. Donna Cruse, Oregon State University, who has done work at the University of Massachusetts and Oregon on the integration of information is also participating.

One product of this framework, we hope, will be an integrated summary of the work being done on semantic memory at various laboratories.

Another goal is to continue our work, begun under the last project, to develop and expand our automated laboratory system for conducting research in information processing psychology. The acquisition of the Prime Computer, which finally arrived in January, will contribute greatly to this. Already, with our PDP-9 and PDP-15 computers we have an advanced facility for conducting a variety of experiments. With the Prime as a new addition to the system, we should be able to conduct almost any type of experiment envisaged under the present project.

We will be devoting some of our resources during the coming year to developing the software for the Prime and integrating this with our current system based on the existing two computers.

## 2.0. CODES AND UNITS

### 2.1. The representation Problem.

A key problem in trying to do research on semantic material is the representation problem. This problem has both a pragmatic and a theoretical aspect. The pragmatic aspect is the need to describe or represent the content and structure of our stimulus materials. Unless we devise adequate ways to describe and quantify the stimulus materials, we will have no way for assessing to what extent, if any, the subjects' outputs are determined by the presented material.

And, in those cases in which we want to fully assess what the subject has extracted or "comprehended", we also have the task of representing or describing his output.

The theoretical question comes from the desire to know how the subject represents or encodes the stimulus information. What is it, in fact, that he is reacting to? What has he grasped of the material he has been given? This question is especially urgent in the present project because, unlike the simple and nonsense stimulus materials, semantic material can be encoded and organized by individuals in almost limitless ways.

Ideally, both the pragmatic and theoretical representation problem can be solved with the same system. But the two representations need not be the same. What is needed is a descriptive system for the stimulus that is sufficient to capture most, if not all, of the possible variability that an individual subject can pick up.

One aspect of the presentation problem deals with the different sorts

of units that might be used to process the information in a stimulus. For example, in written instructional material, one could deal with individual letters, morphemes, individual words, phrases and surface structure units, propositions, sentences, "themes", paragraphs, etc.

As the preceding example illustrates, many types of units often form a hierarchy. Letters are included in words, words are included in sentences, sentences are included in paragraphs, etc. Which of these types of units have psychological consequences? If they all do, how do the components and the wholes relate to each other?

2.2. The Word Superiority Effect.

Two different research projects on our contract have been devoted to what is called the "word superiority effect" or "the Reicher effect". The effect is often called by the latter name because it was Reicher, currently one of our co-investigators, who both developed the paradigm and demonstrated the phenomenon in his dissertation which was published in 1969. Reicher and Harold Hawkins, a visitor from the University of South Florida, have been actively pursuing a new set of experiments based on this paradigm. And Janet Polf, under Hyman's direction, has been doing research on her doctoral dissertation on another aspect of this phenomenon.

The phenomenon was first demonstrated by Reicher in the following situation. The subject is shown a stimulus for a very brief period of time (typically, 30 to 50 milliseconds). The stimulus consists of either a single letter, a string of unrelated letters, or a word. Following the stimulus presentation, the subject is presented with a test consisting of

a pair of letters, one of which was in the preceding stimulus. The subject's task is simply to identify the letter that was in the target stimulus. Reicher found that the subject was more accurate when the letter to be recognized had been part of a word than when it had been presented in isolation or as part of a meaningless set of letters. Other experiments have replicated this finding several times.

For our purposes the phenomenon has interest because of what it might tell us about how higher order units carry information about their components and vice versa. The phenomenon and its accompanying paradigm might be another way to investigate the elusive but obviously very important concept of the "chunk". In the Reicher paradigm, it seems fairly well established that the effect depends in some way on the word being a unitary object. For example, the effect disappears or reverses when the subject has to identify which letter occurred in a meaningless and unpronounceable string of letters.

It also seems that the effect can be affected by whether the subject is focussing upon the individual letters in the stimulus or upon the set of letters as a coherent unit. In the experiment as typically run the subjects tend to encode the entire letter string as a unitary "chunk" rather than as a set of individual letters (or features). This is relatively easy to do when the letter string forms a familiar word or is pronounceable. But it is difficult or impossible to do when the letter string is a meaningless jumble.

Johnston and McClelland, for example, did the experiment under two conditions. In the letter condition, the subject was deliberately instructed to treat the word as a set of individual letters. To further help him in

this task, he was told in advance which letter in the word would be tested. In the word condition, the subject was told to focus on the word as a whole rather than the individual letters. In this latter condition he was not told which letter in the word would be the test letter. Despite this disadvantage, the word condition showed the superior accuracy. That is, when the stimulus was, sav, JOIN, and the subject was told that the first letter was to be tested, he was still less accurate in recognizing whether the first letter had been "J" or "C" than was a subject who had been shown JOIN and told to concentrate on the entire word.

These same experimenters got the opposite result when they gave subjects a letter string such as JPRD and then tested them to see if they could remember if "J" or "C" had been in the stimulus. Subjects in the letter condition were now superior to those subjects who were trying to treat the letter string as a unit.

What sort of a unit or "chunk" is the word in this condition? Is it a visual sort of chunk or code? That is, does the word form a familiar perceptual pattern of visual features, letter combinations, or configuration of some sort? Or is the course of the unit some sort of articulatory or auditory code. Maybe the subject recodes the perceived string letters into some sort of pronounceable sound? Or is there a pyschological unit that corresponds to meaningful words as such?

Reicher and Hawkins have devised a variety of experiments to get at this question. We do know, for example, that prounceability, as such, is sufficient to generate the Reicher effect. But Reicher and

Hawkins believe that words still have a "chunk" or coding effect over and above simple pronounceability. Indeed, there may be a multiplicity of codes or chunking systems any, or all, of which may come into play in given circumstances. It makes sense to suppose that subjects will employ whatever strategies they can to simplify and unitize the material before them. The results of these experiments will be reported in the next report.

Rolf was concerned with another aspect of the Reicher effect. Granted that the subject chunks the letter string into a unit, how does this unit help him to recognize an individual letter that is a component of the chunk? And what is the mechanism by which he does so?

One possibility that Rolf entertained could suggest that the effect was essentially an artefact. Up to now, the Reicher effect has been demonstrated under conditions in which times to respond were not recorded. But some investigators, including Reicher, have informally observed that subjects take more time to respond when the stimulus consisted of a word than when it was an individual letter. Perhaps, in processing a word rather than a letter, the subject simply rehearses the individual letters longer than when he gets a single letter. His subsequent improvement in accuracy, then, would not be because the letter was embedded in a meaningful unit, but because the processing of the unit resulted in the subject spending more time on the individual letters.

Some indirect evidence about time to process words would argue against the preceding interpretation. But other evidence could be mustered in its defense. What is needed is a technique that simultaneously takes both time and accuracy into account. Fortunately, Wickelgren and his student

Adam Reed, partly supported by the current project, have been developing a new speed-accuracy paradigm to simultaneously deal with speed and accuracy within the same experiment and analysis (see below). Polf adapted their procedure to dealing with how the chunk faciliates accuracy in identifying individual components.

Incidently, Polf's dissertation is an ideal example of the type of cooperative research we try to encourage on projects such as this. Polf is doing her dissertation under Hyman's direction. The framework in which her question is posed comes out of the research program being persued by Hyman. But the paradigm that she employs is one developed and currently being used by another investigator in our project, Gerry Reicher. And the methodology (which is another paradigm in its own right) which she applies is one developed by still another investigator in the project, Wayne Wickelgren.

In Reicher's original paradigm, the subject is free to respond when he feels ready. No control nor measure of response time is employed. In Polf's variation, the subject is trained to respond as fast as possible when he hears a tone. As in the Reicher paradigm, the subject is shown a target stimulus which might be a single letter, a string of unrelated letters, or a four letter word. A mask follows the target, then a test pair of letters comes on. The subject has to respond, by pressing one of two keys, to indicate which of the letters was in the target. On some trials, the subject does not know which, the tone to respond may occur as soon as 50 milliseconds after the onset of the test pair, or it may occur as much as 600 milliseconds later. Polf used eight different lags

over this range. Subjectively, the fastest lag occurs too soon to even know what the test letters are, while the longest lag seems to be more than enough time to do all the mental processing that one feels necessary. The subjects have to be trained to respond as soon as they hear the tone regardless of how ready they feel.

The results of this and a second similar experiment clearly exclude the explanation that the Reicher effect is merely a matter of speed-accuracy tradeoff. When the subject takes anywhere from 450 milliseconds or longer to respond, he is clearly more accurate in word than in the letter condition. What is more, the more time he has beyond 450 milliseconds, the more his accuracy improves in the word condition. This added time does not help accuracy, however, in the letter condition. On the other hand, when the subject is forced to respond in less than a half-second, he is more accurate in the letter condition. At the very shortest lags, in fact, the subject behaves at the chance level when forced to respond in the word condition. The data suggest, however, that the subject is better than chance for such short lags in the condition.

Polf's results clearly exclude some possible explanations of the word-superiority effect. But they are still compatible with more than one possibility. Polf is now running additional experiments to try and exclude some of these possibilities. At the moment, the preferred, but still tentative, explanation would go like this.

When the subject receives the test pair of letters he has already fully encoded the target stimulus. In the letter condition, this amounts to simply having encoded the single letter. The exposure duration of the target is such that he cannot always encode this letter with complete

accuracy. But if he has successfully encoded it, his task in the test situation is simply to make a direct match of the stored target with the perceived test letter. While this takes some time, it is still a relatively fast operation, one that does not take more than a half-second to complete. Thus, increasing the response time up to half a second will show improvement in the task, but giving the subject any more time will not help. This, of course, describes the output function obtained by Polf.

In the word condition, the subject encodes the word directly as a unitary "chunk". This chunk, in the words of Johnson, acts an "opaque container". The chunk does not consist directly of the individual letters in the word. But, if called upon to do so, the subject can recover the individual letters by a further retrieval operation. This additional "unpacking" operation, however, takes time. When the subject is forced to respond faster than 450 milliseconds, he does not have time to fully complete his unpacking and tends to make errors. The more time he has, the more accurately he can unpack or decode the word into its constituent letters and check to see which of the test letters is among them.

With sufficient time, the subject should achieve perfect accuracy in this condition (given that he knows how to spell) because once he has the letter string encoded as a familiar word, he can rely upon his previous learning to infer what the component letters must have been. The task in this latter condition is completely process-limited (to employ the terminology of Norman and Bobrow).

But the accuracy in the letter condition will depend, ultimately,

upon how much time was given to perceive the initial target. Even with unlimited time, the subject cannot improve upon his accuracy if he did not correctly register the letter in the first place. In this latter case, ultimate performance is data-limited.

The importance of understanding the dynamics of what goes of this paradigm is not because words as such are improtant units. Rather, we feel that what goes on between words and their components can tell us much about the interaction of higher order units and their constitutents in general. And this, in turn, we believe will turn out to be one of the crucial issues in understanding what goes on during the mastery of knowledge.

2.3. Experiments in "sophisticated encoding".

Other experiments in our project are aimed at discovering the sorts of units or codes that are employed by skilled individuals. Schaeffer has focussed on the acquisition and development of higher order codes. This is difficult to do with adults who come into the laboratory with much of their coding systems already highly developed. One way to get around this is to try to create a situation in which the individual has to develop his encoding units right from the start. To do this, Schaeffer taught individual subjects a simple one-to-one correspondence between Chinese characters and letters of the alphabet. First they memorize the correspondence to the point at which, given a Chinese symbol, they can respond without error by giving the corresponding letter of the known alphabet. Next they are given strings of Chinese characters to decode. The strings are semantically meaningful when decoded into letters of the

alphabet.

What makes this seemingly simpled-minded experiment of interest is that the experimenter can use error analyses and interference tasks to infer the type and size of unit that the subject is using at various stages of his **mastery** of reading with this new code. At first, it is hypothesized, that errors and confusions will conform to visual confusions among the corresponding letters of the alphabet. With gradual mastery of the task, larger and larger segments of the text in Chinese characters should be handled as individual units. At some point, and with sufficient practice, the sorts of chunks and confusions should correspond to what we would observe when an individual reads from texts written in his native alphabet.

The major drawback of such an experiment is that it takes enormous lengths of time, months and maybe years, for individual subjects to achieve sufficient proficiency to give the sort of results that show the hierarchy of units. Consequently, we have to await further developments to see what emerges from this long-range, developmental approach.

Reicher and his colleagues have been approaching the issue of skilled encoding in a different way. Actually, they have been simultaneously trying a variety of converging approaches. In some cases they have obtained highly skilled and less highly skilled individuals in the same task. One such task was sight-reading in music. They found, in agreement with the work on chess grandmasters, that the expert in this task was able to work with chunks of larger size than the no--experts. Simon and others, for example, found that the grandmaster did not excel in the number of "chunks" or units he could handle simultaneously in work-

ing memory. By a variety of converging operations it can be shown that the grandmaster and ordinary masters have the same memory span--approximately 5 to 7 chunks. What makes the difference, however, is that the grandmaster works with chunks that contain more information.

We can illustrate this with a simple experiment that de Groot and others have conducted. A subject is shown a pattern of pieces on a chessboard for approximately 5 seconds. If the pieces represent a position from an actual chess game, the grandmasters can usually reproduce the entire pattern without error (usually around 24 pieces). Ordinary players can get only about 6 pieces correctly placed in such a task. But if the pattern of pieces is random, then the grandmaster and the ordinary player perform equivalently--each getting approximately 6 correct. Thus, something about his knowledge and mastery of the game of chess somehow enables the grandmaster to operate with units or chunks that are of the magnitude of 4 pieces each. A variety of other direct and indirect arguments and experiments seems to indicate that it is in this chunking process that the superiority of the grandmaster lies.

Reicher and his colleagues have shown that it is not just in chess that such superiority of chunking is the key to expertise. The situation seems to be completely parallel with sight readers when compared with musicians who are not expert sight-readers. Other evidence suggests that this is what underlies skilled performance in quality control and other tasks.

So, one method for studying skilled encoding is to compare experts with non-experts in the same task. A parallel way is to train individuals

on coding procedures that seem to underlie skilled performance. A third method is to employ a task in which most adults are already highly skilled, but to control the input in a variety of ways in order to tease out what the basic units and hierarchies of units actually are. Reicher is involved in all of these approaches. At the moment, for example, he is devising a method using the computer-controlled scope to control both the size and pace of what his subjects are reading.

Another approach being developed by Reicher is inspired by the frequent reports that, for skilled individuals, the appropriate object they are seeking amidst a collection of homogeneous objects seems to "pop out" from the background. In some of their experiments, for example, the background is composed of letters, while the target is one or more letters in abnormal orientation (mirror-image, upside down). With some practice, the target letter seems to "pop out" almost instantly when presented with the test array. But when the target is a letter or familiar object innormal orientation against a background of letters which are all in abnormal orientation, the task is enormously more difficult. One possibility is that organisms are constructed so as to attend to the unusual or unfamiliar. And when the background is composed of unfamiliar elements, the subject has great difficulty in disregarding it.

This has relevance to extracting meaningful and relevant material from a larger body of information. Data have already been collected in other laboratories that indicate that such a task is relatively easy when the material to be abstracted is unfamiliar, but embedded in a familiar or coherent background. But the task is relatively difficult when the

relevant material is familiar and coherent, but embedded in a background that is unfamiliar or incoherent.

Our hope is that pursuit of this issue will give us clues as to how successful individuals are able to attend to just that part of a complex body of information that is relevant to their task.

## 3.0. THE SPEED-ACCURACY PARADIGM

Much of the classical approach to memory and verbal learning focusses upon accuracy of responding. One thing that distinguishes the information processing approach to memory and similar problems is the focus upon speed of response. In the latter approach, sometimes errors are also recorded, but only to show that they do not make much difference in the specific experiment being discussed.

From time to time, an investigator will urge that we study the joint operation of speed and accuracy within the same paradigm. What information we have suggests that, in many situations, errors and time are interchangeable--that is, they both reflect difficulty in dealing with a task. if a discrimination is very difficult, the typical subject will take longer to make it. He will also tend to make errors. Consequently, for many types of experimental paradigms, experimenters have treated it as an arbitrary decision as to whether to use time or accuracy as the dependent variable.

But there are situations and occasions when it seems that speed is achieved at the expense of accuracy. When this is the case, errors and time vary inversely. It can be quite misleading in such cases to use either time or errors alone to draw conclusions. Both are necessary to avoid wrong conclusions.

Wickelgren and his student Adam Reed have been working on both the practical and theoretical aspects of a paradigm that would simultaneously take both speed and accuracy into account. The sort of speed-accuracy paradigm they have found optimal is one based on the use of an auxiliary response signal. We have described this procedure in the preceding discussion of Janet Rolf's dissertation.

When properly employed, the technique generates a speed/accuracy tradeoff function. On the horizontal axis of a graph, one plots the total time from onset of test stimulus to subject's response. Because the subject has been trained to respond only when the auxiliary signal occurs, the experimenter can ensure that he has data from the complete range of intervals that are crucial for understanding the processing stages in a given task. On the vertical axis, some measure of accuracy--usually d'--is plotted for each response interval. The resulting function supplies the experimenter with at least three measures, depending upon the form of the function.

One measure is the intercept. This corresponds to the time between the test onset and the subject's response interval that first shows signs of being more accurate than chance. A second measure is the asymptote. This is the maximum degree of accuracy that the subject can achieve even with unlimited time. And finally, there is the rate parameter which indicates how fast the subject goes from above chance accuracy to maximum accuracy. A typical function might show an exponential curve which gradually approaches assymptote.

Wichelgren has drawn several interesting theoretical observations

about both this paradigm and its theoretical import. He has made a strong argument for using this paradigm in most situations in which we want to study mental operations during the time they are occuring rather than after they have been completed. He has also shown how many previous experimental findings, a striking example being the well-known Sternberg paradigm and its findings, are ambiguous because they have not employed a speed/accuracy paradigm.

One unexpected conclusion is that accuracy measures are probably less subject to biases and distortions than are reaction-time measures. This is because reaction time measures are typically collected under conditions in which subjects are encouraged to be accurate. Indeed, the experimenter usually considers it a virtue if the error rate is low in such experiments. A low error rate is often cited as the reason for not being concerned about a possible speed-accuracy confounding. But as Wickelgren points out, the speed-accuracy function shows that low error rates coincide with that part of the function where a very slight difference in errors corresponds to a hugh difference in response time. Thus, with only a few errors, the experimenter might interpret the differences between mean times for conditions as being due to capacity or difficulty, when in fact, it might be due to a willingness to be less accurate in one condition as opposed to another. On the other hand, enormous differences in latency, beyond a certain point, correspond to very small differences in accuracy.

3.1. Application of the Speed/Accuracy Paradigm.

The most successful and satisfying application of this paradigm so far has been Janet Polf's dissertation which was described above. In

addition, two of Wickelgren's students, Barbara Dosher and Albert Corbett have used the paradigm in their Masters Theses performed under the sponsorship of this contract.

Dosher used the paradigm to gain information about which of a number of ways to represent the structure of a proposition coincides with the way such information is actually represented in an individual's memory. She had her subjects learn sets of sentences that consisted of subject, verb, object, location, and time. Subjects were then tested with various combinations of such constituents (say S and B) as cues to see how well they enabled them to retrieve the rest of the sentence.

Dosher's speed-accuracy functions revealed that context was indeed treated separately from the subject-verb-object combination. But the subject-verb-object combination behaved as a unit in retrieval, contrary to the model of Anderson and Bower. Dosher also concluded that her data were consistent with a continuous buildup of information about the sentence during retrieval.

Corbett applied the paradigm to test different models of how individuals learn to classify objects in a quasi-semantic system. His students learned a set of patterns that varied in whether they were crosses or I's and in terms of the length of the horizontal and vertical components. They learned both a major and minor category in which each pattern belonged (hierarchial system), labels for the individual items as well as subordinate and superordinate categories. The subjects were tested both on visual and verbal aspects of the system. In the perceptual task,

the subjects classified the pattern as if they were employing a weighted prototype of the visual features. This tends to support pattern recognition work of Hyman and Frost, Posner and Keele, and others. But the verbal task suggested that they did not carry over this strategy to the figure names. It could be that the speed-accuracy task encouraged two different strategies depending upon the form of the stimulus material. Corbett is pursuing the dynamics of classification systems in semantic memory for his doctoral dissertation.

4.0. THE IMPRESSION FORMATION TASK.

We wanted to devise a general paradigm that would enable us to investigate how what the subject already knows influences his encoding of new input. Not that we doubted the fact that such an influence takes place. To the contrary, much research going back to Bartlett's 1932 classic on remembering and continuing with contemporary research such as that by Bransford, Franks and their co-workers leaves no doubt that what is retained is decisively controlled by how it was encoded.

We wanted to go beyond the further demonstrating of something that we all agree upon. We wanted to see if we could control some of the factors that determine the initial encoding and make differential predictions about the outcome.

One approach to this was Hyman's adaptation of the impression-formation task. In this task, the subject is given a description of a hypothetical individual and then describes his impression of that individual on a checklist. The social psychologists typically concentrate upon factors that affect the subject's impression. Hyman adapted this task to focus on factors that affect the subject's memory for the initial

description of the individual. The interest is not so much in how accurately he can remember, but rather in the nature of the distortions or errors in memory that occur. Such errors can be used to indicate how the subject has organized and encoded the initial material.

The resulting paradigm has many attractive features. It is easy to generate normative data to indicate how typical subjects react to different descriptions and category labels. The impression task, itself encourages the subject to form a coherent organization of the given material without having to tell him to memorize the material. As a further bonus, the impression task provides us with information about the subject's initial impressions or inferrences about the stimulus material. We can thus compare subsequent memory not only against the original stimulus but also against the subject's initial description of that stimulus. And, finally, the subjects tell us that they enjoy the task and think it is relevant to what they do in everyday affairs--make judgments about people on the basis of partial information.

Hyman reported the first experiment using the paradigm at the Tenth Annual Carnegie-Mellon Conference on Cognition at Vail, Colorado in June, 1974. This will be published in the forthcoming book edited by David Klahr called "Cognition and Instruction."

4.1. <u>The Basic Experiment</u>.

The subject is presented with a short description of a hypothetical individual. The description includes three components: (1) the individual's name (e.g., Robert Caywood); (2) the individual's occupational major (e.g., Accountant); and (3) a short character sketch written around 10 adjective-traits (such as "withdrawn", "deliberate", ect.). The sub-

ject's task is to form a coherent impression of what this individual is like. He then describes his impression by circling those adjectives on a checklist of 91 traits that fit his impression. He performs this task for three different hypothetical individuals.

Of the three descriptions, one of the pairings of occupational label and sketch is chosen to be "appropriate" and the other two pairings are chosen to be "inappropriate". Appropriateness of the matching was decided on the basis of normative ratings by a separate group of judges. Different groups of subjects get different pairings of the same set of sketches and labels to counterbalance specific effects of a given label and sketch.

Following the impression task, the subject is then told that we are also interested in his memory for the sketches that he read. His memory for these sketches is tested by giving him the list of 91 adjectives. He is given the name and occupational label of one of the descriptions (e.g., Robert Caywood, the Accountant). He then goes through the list of adjectives and indicates which ones he believes were in the original sketch of Caywood. For each adjective he indicates not only his judgment, but also his degree of confidence in that judgment. Essentially, this amounts to a rating of each adjective from "1" (very confident that it was in the sketch) through "6" (very confident that it was not in the sketch).

The purpose of the first experiment using this paradigm was to look at the effects of discrepancy from stereotype upon recognition memory. In the appropriate matching of category to sketch, we would expect a high "hit rate"--that is a strong tendency to rate high those adjectives that were actually in the sketch. At the same time, however, we would expect

a strong "false alarm rate"--that is a strong tendency to also rate high adjectives that were not in the sketch but which are consistent with the stereotype that goes with the category label.

When the category label was grossly mismatched to the character sketch, we expected to observe both a low "hit rate" (since the category label no longer helps to suggest which adjectives are relevant) and a low "false alarm rate" to objectives that are related to the category label (because the subject probably remembers that this individual was not typical of accountants, etc).

The most interesting case for our predictions was when the label was only mildly inappropriate. Here we hoped that the mismatch would not be too obvious, encouraging the subject, instead, to generate a coherent impression that integrated label with sketch. We expected most memory distortion to occur in this case. Here we expected the impression of the sketch to be assimilated to the category label. Whereas in the case of the grossly inappropriate label, we expected a contrast, rather than an assimilation effect.

The experiment, thus, predicted different sorts of memory for three different degrees of appropriateness. The experiment failed in helping with this prediction because, in fact, it turned out we had effectively just two levels of appropriateness-- an appropriate match and a mildly inappropriate match. Indeed, it is quite difficult to generate a sketch and a label that most of our subjects cannot integrate into some sort of a plausible impression.

As expected, appropriate labels tended to reinforce the tendency to false-alarm to adjectives that fit the stereotype that go with the label.

When Robert Cawwood, whose sketch is appropriate to the image of an accountant, is labelled as an accountant our subjects tended to falsely remember that he was described as "mathematical", "careful", "consistent", "methodical", "precise", "systematic", and "economical" much more frequently than when the same sketch was labeled as that of a "Social Work" or "Lawyer" major.

However, our results make it clear that we cannot simply conclude that memory is distorted to fit the label. We have to qualify such a conclusion in at least two ways. One way is that distortion occur mainly when the label is appropriate. An appropriate label tends to encourage false recognition of adjectives that are consistent with the label. But inappropriate labels, in general, do not encourage false recognition. There is little overall tendency to falsely recognize adjectives that are related to the label when it is inappropriate.

Accuracy of recognition, as determined by the relative ability to discriminate correct adjectives from related foils, is just about equivalent for the appropriate and inappropriate labeling conditions. In the inappropriate condition, there are fewer false alarms, but there are also fewer hits.

The preceding conclusions are correct when we average over the three different sketches. But they must be further qualified because of specific interactions between particular sketches and particular labels. One of the sketches, "Robert Cawwood", was written to be compatible with the stereotype of "Accountant". The major effect for this sketch occurs when the appropriate label is assigned to it. This enhances strongly the tendency to falsely remember Cawwood as having

been described as "systematic", etc. At the same time, when assigned the label of "Social Work", or "Lawyer", no tendency emerged to falsely recognize adjectives relevant to either of these latter two labels.

The sketch "Decker" was written to be compatible with the stereotype of "lawyer". The major memory distortion that took place with this sketch was when it was assigned to the category "Social Work". This latter label strongly enhanced the tendency to falsely remember that Decker was described as "charitable", "friendly", etc.

The third sketch, "Fleming", was written to be compatible with the stereotype of "Social Work". Here we found that the application of the appropriate label reduced the tendency to falsely remember adjectives appropriate to an accountant. In addition, assigning the label "Lawyer" to Fleming increased the tendency to falsely recognize such adjectives as "persuasive", "aggressive", etc.

In short, the label does make a difference in recognition memory. The specific effects of the label, however varies with the sketch and the label. The sketch for Caywood differs most from the other two sketches on a number of independent and normative measures. For this reason, it is probably most difficult for the subjects to perceive Caywood as a plausible lawyer (he is described as "withdrawn" and "distant") or a plausible social worker (also because of his anti-social traits). As a result it is possible to distort both the impression and memory for Caywood towards the image of a withdrawn, meticulous, compulsive individual by appropriate labels, but it is probably difficult to distort the image of Caywood towards the generous and warm stereotype of the Social Worker or the extroverted and forceful image of the Lawyer. The sketch

for Fleming describes his warm and generous social tendencies. Calling him a social worker confirms these tendencies and contrasts them with the cold and niggardly image of the accountant. Labeling Fleming an accountant does not make it easy to assimilate his good-guy picture to the socially negative traits that form the stereotype of an accountant. But there is no incompatibility of being socially positive and being aggresively persuasive, even though these two might not be highly associated. Consequently labelling Fleming as a Lawyer makes it easy to attach to his existing image the traits of a lawyer.

Additional findings from the impression task add to these results. Almost all of the effects we find on the recognition test are found in the impressions as indexed by the check list. This finding excludes the possibility that we are dealing with a bias that is induced by the label at the time of recognition testing. Because the impression task occurs immediately after initial exposure to the sketches, the evidence is that the memory effects are due to the initial encoding of the sketches and not to subsequent effects of the label at testing. Further analyses (analysis of convariance and related tests) indicate that the impression is not the cause of the recognition memory, but is, itself, a dependent variable which is also affected by the initial encoding.

4.2. Subsequent experiments with the Paradigm.

We conducted two additional experiments within this paradigm. Both are identical to the basic experiment with only minor changes. In the second experiment, we inserted a free recall task in between the impression and recognition memory tasks are basically the same as for the first experiment. The recall data tend to show the same results as do the

recognition data.

The third experiment attempted to emphasize the effect of the label. It did so by first having the subject form his impression to the individual first on the basis of the label alone before he was shown the character sketch. Again, the results simply confirm those of the previous two experiments.

4.3. Additional variations.

We tried a number of variations on the basic paradigm. One reason is that our initial sketches were internally consistent. Against such a homogeneous set of 10 descriptors, the category label--especially when inappropriate, was relatively impotent. The label effects while highly consistent and significant were quite small relative to the hugh effects due to the overall sketch effects (we also had normative data on the impressions generated by the sketches in isolation from the labels). A more fruitful approach, we reasoned, was to create inconsistency within the sketch itself.

We created a new paradigm to do just this. One of the experiments we completed was done as follows. The subject is given a coherent and homogeneous character sketch of a hypothetical individual. As in the previous experiments, the subject forms an impression and describes it by means of a check list. Then we supplied the subject with additional information about the given individual. The new information is also in the form of a character sketch. But half of the new information is consistent or "appropriate" to the original information and half is not. We then have the subject form a revised impression of the hypothetical individual. Finally, we have him indicate his memory for all the adjectives

used to describe the individual in a recognition test.

The subjects tend to give the same ratings (have the same "hit rates") for both the consistent and inconsistent information in the second sketch. But the false alarm rates for associated foils are quite different. The subjects have high false alarm rates for foils that are consistent with the initial sketch; they have low false alarm rates for adjectives that are related to the inconsistent information.

This indicates that the subjects encode consistent information in a highly generic way. If the hypothetical individual was initially described as socially outgoing and warm, they will encode a consistent adjective such as "charitable" as simply confirming the "good-guy" image. In later recognition testing they will not only tend to correctly recognize "charitable", but also "friendly", "helpful" and other adjectives that were not in the sketch but which are consistent with the "good-guy" image. But if the hypothetical individual had initially been described as socially withdrawn and calculating, they will tend to encode the now-inconsistent adjectives such as "charitable" in a highly specific way to make it compatible with what they already have learned. In this second case "charitable" will not be encoded as consistent with a "good-guy" image, but rather something specific might be extracted such as a man who donates to charities in order to gain an income tax benefit. In this latter case there will be no tendency to confuse, in later recognition, the memory of "charitable" with foils such as "friendly", "generous", etc.

5.0. Loading data bases.

The question we keep asking in relation to our project is: how

does what you already know affect your ability to deal with new, relevant information? The complementary question is: how does the new information affect what you already know? The difficulties in experimentally investigating these questions include the awesome task of adequately specifying the initial data base that the subject brings with him to the task.

In our initial proposal for this project, the basic strategy for dealing with this problem was simple in principle. We would construct artifical, but semantically meaningful, data bases representing small segments of a possible knowledge system. We would then "load" such data bases into our subjects' memories. To the extent we succeeded in such a direct implantation, we could then proceed with various experimental tasks which could confidently assume a known data base. The initial data base could be varied in a variety of ways and the new information to be mastered could be varied correspondingly to bear specified relationships to the data base.

During the first year of the project, Hyman, Polf, and Weddell tried to implement this paradigm and test its efficacy. We completed three experiments. The second experiment, which is typical, will be described here. The data base, consisted of a set of names ("objects"). Each name was characterized by its value or property on one of four dichotomous attributes (occupation, geographical origin, hobby, and attitude towards a political issue). The information about the hypothetical individuals was embedded within a prose narrative about a town called DiJon. Each subject read the narrative at his own pace and in his own way with the goal of mastering all the information about each individual.

When the subject felt ready, his mastery of the material was tested. The test consisted of his being able to correctly recall all four properties about a given individual when presented with his name. After the subject had successfully demonstrated his mastery of the data base by this criterion, he was then allowed to enter the experimental phase of the study. The experimental testing consisted of eight separate experimental sessions spread over an approximately two-week period.

A session consisted of trials on which pairs of names were displayed on the cathode screen controlled by the PDP-15. For any given session one attribute was designated as the target for that day. For example, if the target was "occupation", the subject was to respond "same" (by pressing a key) whenever the pair of names was the same with respect to occupation. Otherwise he pressed the key indicating "different". We were interested in the extent to which the subject could respond to the pair on the basis of occupation without being affected by the other properties on which the same pair of names could be same or different. As expected, on the basis of pilot data and from our extrapolations from somewhat related studies, the speed to say that two names were the same on a target attribute was strongly affected by the number of non-target attributes that the pair of names were the same on. For example, reaction time to say that a pair of names was same on "occupation" was fastest when the pair was also the same on the non-target attributes of geography, hobby, and attitude. It was next fastest when the two names shared two out of three of the non-target properties. It was slowest for the case in which the two names did not share any of the non-target attributes.

These data suggested that the subjects could not selectively retrieve just that information that was relevant to the given task for the session. One possible model was that during initial mastery of the data base, the subjects stored a list of the properties with each name. When they had to compare two names on a given property, they did so by retrieving the entire list of properties with each name and then searching through the property lists in a fixed order regardless of the given target. Even with practice lasting over eight sessions, the subjects did not seem to achieve the ideal of selective retrieval in this task.

As it stands, this finding strongly implicates the organization of the data base during initial learning as the strong, almost inflexible, determiner of how the information is retrieved and used in subsequent tasks. Further confirmation of this viewpoint occurred when one of our subjects showed, right from the start, no effect of the non-target attributes in making her matches. On inquiry, we discovered that this anomalous subject had organized the material differently from the others during initial learning. The other subjects all employed a learning strategy that associated all four properties together with the appropriate name. But this deviant subject had learned the information about which names had a given property separately for each attribute. She first mastered the information on geography by creating an alphabetized list of all those who lived in the East. She then memorized that list. She had only half the list of names to learn because she could infer that anyone who did not live in the East must live in the West. Once she had mastered the information about geography, she then independently learned

who were the Farmers on the occupational attribute. In a like manner she learned the information about the other two attributes.

We checked this out in a subsequent experiment in which we brought back all of the subjects in the original experiment after a lapse of two weeks. We now employed an experimental task aimed at determining to what extent the subjects had the property information for each name stored as a single list or as a bunch of independent associations (to put it differently, to what extent was the information stored by name or by attribute). On each trial, the subject was given a name and a single property. He had to respond as fast as possible with a "yes" if that property was true of that name. For all the subjects except our deviant one we found that the speed of responding to any one property for a given name was highly correlated with the speed of responding to any other property for that name. This further demonstrated that our deviant subject was deviant in that she did not have the information about a given subject all stored in one place.

A further finding was that this deviant subject showed the most forgetting over the two week period.

We tried to do further experiments to deliberately manipulate the way in which subjects organized the initial data base. But, in addition to many technical problems, we found it impossible to force a given organizational strategy upon our subjects.

To our surprise the difficulty with this paradigm was not in the "loading" phase. We could, with patience, load rather elaborate data bases into a subject's memory. Our major problems involved inadequate tools for constructing data bases and an overwhelming complexity in trying

to counterbalance for the various possible confounding factors. We were also dismayed by the unexpectedly complex data analyses required.

We set this paradigm aside and went on to other work while trying to reconsider how to implement the original plan.

5.1. Nominal and Relative Data Bases.

In retrospect, some of our problems with the initial experiments stemmed from the lack of sophisticated descriptive tools. Our data base, while fairly complex with respect to typical learning experiments, were still semantically very primitive. Our entire data base could be viewed as set of nominal propositions. That is, each molecule of information consisted of an object (a name) and the attribution of a property. We call such a system "nominal" (after Frederiksen) because it serves to identify each object in terms of a classification or attribution without directly linking any object in the system with another object. Whatever organization is created in such a system depends upon objects having shared properties. Such linkages are indirect, occurring through the possession of common elements.

As contrasted with nominal propositions, relative propositions specify a direct relation between two objects. If we say that X is the father of Y, for example, we have a relative proposition that specifies a linkage of a particular sort between the objects X and Y. For the sorts of questions that we were trying to answer in our original experiments, we felt we would gain much more power by employing both nominal and relative propositions within the same experiment. Accordingly we have devised a set of new paradigms that are somewhat more sophisticated versions of the earlier paradigm.

The new experiments differ from the earlier ones in a number of crucial ways. In one sense, they are much less complex. We employ fewer objects in the data base and fewer attributes. On the other hand, we load the data base into a subject's memory in two stages. We first create, for example, a data base from nominal propositions (a lexicon). Once the subject has mastered the first data base, we then teach him a new set of propositions involving the same objects. The new set of propositions are relative, specifying direct relationships between pairs of objects in the initial data base (the relational system).

The experimental task consists of having the subject verify as "true" or "false" new propositions involving the objects in the data base. The new propositions are all relative, specifying relations between the objects in the lexicon which may be true or false. The subject can verify a proposition by using only the information from the relational system. What we are interested in is the extent to which he also uses information from the initial data base to verify the statements.

5.2. Family relationships.

In one paradigm, the subject first learns, for each of a set of names, the sex and age (male or female; age 30 or 5). The names are all neutral in gender so that they do not serve as a cue, (for example, "Chris", "Pat", "Dana", etc.). Once he learns the nominal data base of sex and age, he then learns new information about the individuals in the data base--namely who is related to whom and in what way. For example, he may be told that Chris and Kim are the parents of Pat and Dana. He is told a similar relationship system for the other four names in the data base. This information, along with the subject's knowledge of kinship systems and his mastery

of the original data basis should be sufficient for the subject to answer such questions as: Pat is the husband of _____? Pat is the father of _____ and _____? Dana is the daughter of _____ and _____? To be sure, the subject is tested on all possible pairwise relationships between members within a family.

The experimental test consists of giving the subject statements such as "Chris is the father of Jan". He has to respond as rapidly as possible with "True" or "False". We look for the differences in saying "False" to statements in which the two individuals share zero, one, or both properties of age and sex. If the subject's are using the information "associatively" (on one model, for example) we would expect the reaction time to say "different" to be slowest when the two names (the subject and object) share two properties (they would be stored together in the lexicon). On the other hand if the subject is using the information "semantically", we would expect the subject to be slower in saying different when the two names are different in age (because this is semantically possible, but semantically impossible when the two names are the same age).

5.3. Friendship relationships.

The relation of friendship differs from kinship relation in several ways. It can be reciprocal; it does not order the names in any systematic manner; etc. In a second set of experiments we employed this reaction instead of kinship. The nominal data base consists of names and two properties associated with each name--height and geographical origin. Once this nominal system is mastered, the subject then learns which subsets

of individuals are friends to one another. In these experiments we always use the friendship relation as symmetrical. If X is a friend of Y, then Y is a friend of X.

With these alterations, the experiments are otherwise parallel in all details.

4. Some tentative findings.

Because these new experiments have just been initiated we have only some tentative data to report. When the relational system is learned at a separate time from the nominal system, for example, we find that, on the average, verification latencies to relational propositions are not influenced in any systematic manner by the information in the nominal data base. This ability to compatmentalize the two systems could be due to their having been learned at separate times or because the two sorts of systems generate organizational structures that can be kept separate from one another.

On the other hand, we find that subjects cannot react selectively to comparisons based on one of the nominal attributes without being affected by information from the other nominal attribute. This effect, however, is different from what we would have predicted from the sort of associational model we found compatible with the earlier experiments. If the subject, for example, has to decide if a pair of individuals is the same or different on height, the decision is faciliated--regardless if it is positive or negative--when the two names are the same in geographical origin. This finding is symmetrical. Subjects make faster comparisons on geography if the two names are the same in height.

The finding is compatible with a model that says that the first name of a given pair serves as an entry point into the memory structure. The subject then starts to look for information about the second name at the same address. If the other name happens to be stored at the same location (shares other nominal properties) the retrieval and comparison is relatively fast. If not, the response is slowed down.

We are planning to better control the way the subject has the nominal data based organized by teaching directly a spatial organization for the data base. One situation, for example, will involve a data base on which names are arrayed on a two-dimensional geographical grid. Subjects will be taught the data base in terms of this grid. We can then test to see if in fact the underlying memory structure has either or both the topological and metric properties implied by this organization. We then can test the implications of superimposing upon this spatial organization a relational system such as the family or friendship systems.

## 6.0. EXTENSIONS.

The data bases discussed in the preceding section are still relatively primitive. Both the nominal and relational systems employed are all stative systems--that is sets of propositions that identify objects in terms of static classifications, attributes and dispositions, and static relationships to each other such as friendship and kinship. Such data bases correspond to part of what is termed "semantic memory" and to "subjective lexicons". Of more interest will be the investigation of how such semantic memories operate in dealing with episodic events and vice versa. For this latter purpose we will have to introduce action systems and locative-temporal systems. That is, we will want to specify or

describe episodes involving actions between individuals in the data base that occur in particular places and times.

6.1. Other directions

We have been considering other directions. We are interested in pinning down experimentally different contextual effects. We especially are interested in using information processing procedures to determine at what point in the attempt to comprehend materials the context enters the picture. Tram Neill, in collaboration with Hyman, is investigating the use of opposites and synonyms for this purpose. We have found a scattered literature, that does not seem to involve communication between the separate investigators, that seems to indicate that under some conditions opposites behave like synonyms and under other conditions they do not. Because we feel that this may be a context effect, we plan to see if we can bring some order into this area.

In relation to this preceding project, we also plan to study the influence of attention in encoding of new material.

Hyman has been studying the effects of prior information and preconceptions on creative achievement and innovation, on comprehension, and on gullibility. The distinct possibility exists that all these phenomena depend upon the same underlying psychological processes (inference mechanisms that go beyond the given data in order to "make sense" out of them). This work has just begun. It is related, at a theoretical level, to the problems of chunking discussed earlier in this report.

Finally, as indicated at the beginning of the report, we are pursuing our development of framework around which we hope to integrate

the information in the new field of semantic memory.

## 7.0. WICKELGREN AND HIS STUDENTS.

We have already discussed the development of the speed-accuracy paradigm and its theoretical justification by Wickelgren. We have also described the applications of this paradigm by two of Wickelgren's students, Barbara Dosher and Albert Corbett. Wickelgren has also been very productive in developing and testing theoretical models both in classical and semantic memory. In classical memory, he has been developing his single-trace theory and showing its superiority to the previously prevalent dual-trace theory (which separates memory into separate components of short and long term memory). The new single trace theory attempts to explain many memory phenomena in terms of two closely coupled properties of the trace--strength and fragility, both of which decline with time in storage. Wickelgren has tested important implications for this new single trace theory upon learning and forgetting under alcohol and in terms of the effects on age. These tests and the underlying theory will be included in a series of publications.

In the realm of semantic memory, Wickelgren has published a theoretical paper that classifies various propositional representations of memory into three basic types--relational, predicate, and operational grammers. He argues from a theoretical point of view against the first, even though this is probably the most popular among current systems to represent semantic memory. He theorizes that the second is characteristic of left-hemisphere thinking, while the third is characteristic of right-hemisphere thinking. Wickelgren's pupil, John Winkelman has theoretically examined and evaluated four representational systems for

kinship systems in terms of their ability to adequately deal with reasoning processes. He shows that the currently popular systems are inadequate and suggests that an albebraic system, which he devised, is superior for many purposes.

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This research is a continuation of earlier studies involved in understanding how learners encode information for storage in memory and the effect of the encoding process on retrieval from memory storage. Current research is extending the investigation to the storage and recovery of semantic (meaningful) information rather than unrelated units of information. ~~Dr. Hyman~~ and his associates are working on the process of "chunking" information into units as an influence on memory. They are also ~~Dr. Reicher is~~ investigating the differences in


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encoding that characterize sophisticated learners as compared to novice in a subject matter field; ~~Dr. Wickelgren~~ is performing studies of memory in the mode of classical and semantic memory formulations.

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